Tertiary or Enhanced Oil Recovery (EOR) processes

The oil recovered by both primary and secondary processes ranges from 20 % to 50 % depending on oil and reservoir properties.

Table 1 summarize the oil recovery efficiencies from primary and secondary recovery processes obtained from production data from several reservoirs in the United States.

As Table 1 shows after primary and secondary oil recovery, a significant amount of oil is left behind in the reservoir.

	Recovery Efficiency			
Reservoir Location	Primary %OOIP	Type of Secondary Recovery	Secondary % OOIP	Oil Remaining % OOIP
California Sandstones	26.5	Pattern Waterfloods	8.8	64.7
Louisiana Sandstones	36.5		14.7	48.8
Oklahoma Sandstones	17.0		10.6	72.4
Texas Sandstones	25.6		12.8	61.6
Wyoming Sandstones	23.6		21.1	55.3
Texas carbonates	15.5		16.3	68.2
Louisiana Sandstones	41.3	Edge Water Injection	13.8	44.9
Texas carbonates	34		21.6	44.4
California Sandstones	29.4	Gas Injection Into Cap	14.2	56.4
Texas Sandstones	35.3		8.0	56.7

Table 1: Oil Recovery Efficiencies as % of OOIP from primary and secondary recovery.

Enhanced oil recovery processes include all methods that use external sources of energy and/or materials to recover oil that cannot be produced, economically by conventional means.

EOR refers to the recovery of oil through the injection of fluids and energy not normally present in an oil reservoir to improve oil recovery. The goal of enhanced oil recovery processes is to recover at least a part of the remaining oil in place.

The general mechanism of oil recovery is movement of the hydrocarbons to production wells due to a pressure difference between the reservoir and the production wells. Thus, the objectives of the enhanced oil recovery are to increase the pressure difference between the reservoir and production wells, or to increase the mobility of the oil by reduction of the oil viscosity or decrease of the interfacial tension between the displacing fluids and oil.

The injected fluids must accomplish several objectives as follows:

a- Increase the natural energy in the reservoir.

b- Interact with the reservoir rock/oil system to create conditions favourable for residual oil recovery that includes among others:

- Reduction of the interfacial tension between the displacing fluid and oil.
- Reduce capillary forces.
- Increase the drive water viscosity.
- Oil viscosity reduction.

The ultimate goal of EOR processes is to increase the overall oil displacement efficiency, which is a function of microscopic and macroscopic displacement efficiency.

Enhanced oil recovery processes have as their objective the increase of recovery from reservoirs depleted by secondary recovery with waterflooding or gas injection. The EOR processes can be divided into three major categories: (1) chemical, (2) thermal, and (3) miscible. The major enhanced oil displacement processes can be further subdivided into various categories as illustrated in Fig. 2. Thermal processes have been used extensively for the displacement of heavy oils, whereas chemical and miscible displacement processes have been employed for the recovery of light oils.

Chemical flooding processes can be divided into three main categories: (1) surfactant flooding, (2) polymer flooding, and (3) caustic flooding. The mechanism of oil displacement by surfactant and caustic flooding is based on the formation of ultra-low interfacial tension, whereas polymer flooding alone, or injection of surfactant followed by polymer flooding, results in controlling the mobility which in turn enhances oil recovery.

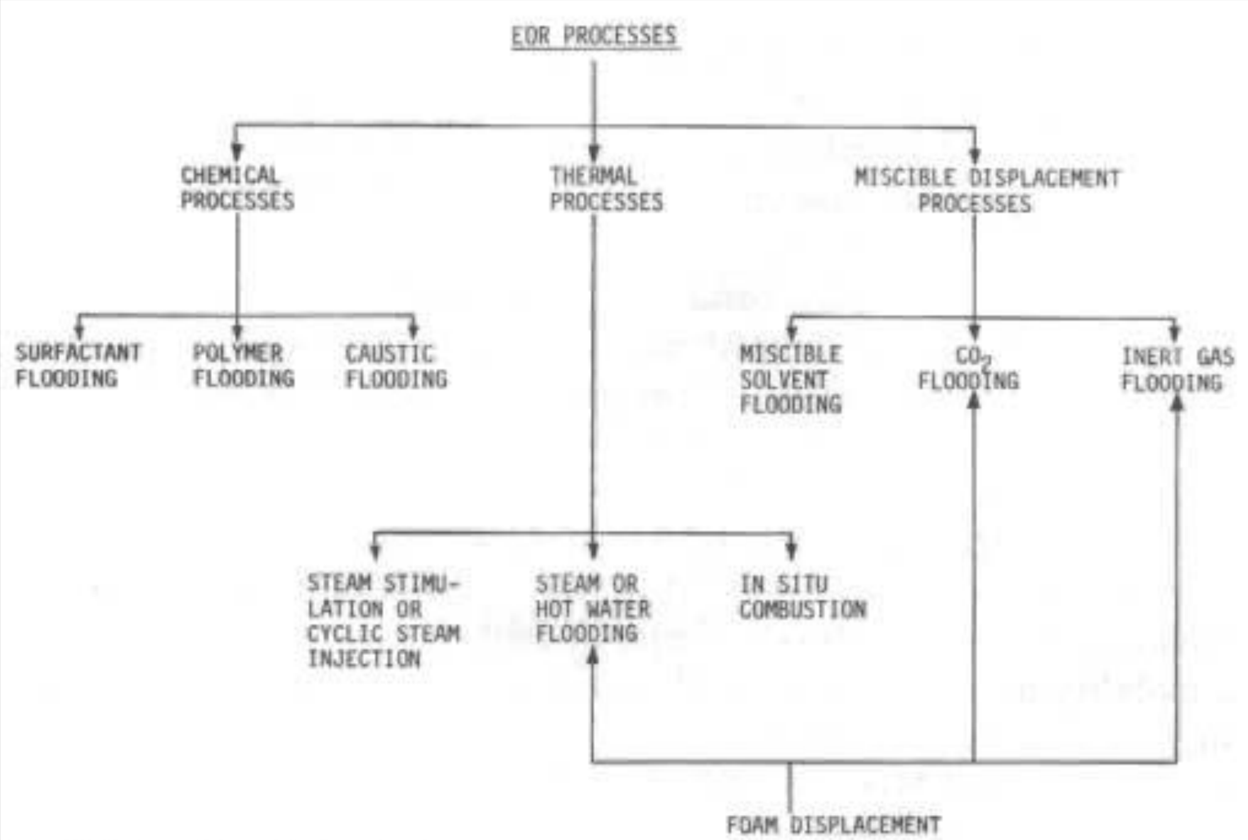

Figure 2: Various EOR processes.

When petroleum reservoirs contain a low-gravity (less than 20o API), high viscosity oil and have a high porosity, secondary recovery methods are not effective for displacement of oil. For such reservoirs, thermal processes have received the most attention. The injection of steam reduces the oil viscosity which causes an increase in the oil mobility. Depending on the way in the heat is generated in the reservoir, the thermal processes can be divided into three categories: (1) in-situ combustion, (2) steam injection, and (3) wet combustion.

The miscible displacement process involves the injection of a solvent such as alcohol, refined hydrocarbons, condensed hydrocarbon gases, liquefied petroleum gases, or carbon dioxide, which can dissolve in the reservoir oil. The injected solvent reduced the capillary forces that cause oil retention in the pore spaces of the reservoir rocks. In this process, the injected solvent slug is followed by the injection of a liquid or gas to force the solvent-oil mixture out. The miscible displacement process can be subdivided into: (1) the miscible slug process; (2) the enriched gas process; (3) the high-pressure, lean gas process; and (4) the mutual solvent and carbon dioxide processes.

1- Chemical methods:

Chemical methods of enhanced oil recovery are characterised by the addition of chemical to water in order to generate fluid properties or interfacial conditions that are more favourable for oil displacement. This can be done in many ways:

a- Increasing water viscosity.

b- Decreasing the relative permeability to water.

c- Increasing the relative permeability to oil.

d- Decreasing the interfacial tension between the oil and water phases.

Chemical flooding is a generic term for injection processes that use special chemicals dissolved in the injection water that lower the interfacial tension between the oil and water from an original value of around 30 dynes/cm to 10-3 dynes/cm. At this low interfacial tension value, it is possible to break up the oil into tiny droplets that can be drawn from the rock pores by water.

The efficiency of the chemical flooding is a function of liquid viscosity, relative permeability, interfacial tension, wettability, and capillary pressure. Even if all the oil is contacted by the injected chemicals, some oil would still remain in the reservoir. This is due to the trapping of oil droplets by capillary forces due to high interfacial tension between water and oil.

There are three main types of chemical flooding processes:

1- Polymer flooding

2- Surfactant flooding

3- Alkaline (caustic) flooding